

Case Studies – Alternative Energy Projects in the DoD

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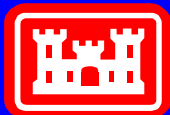
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25 APR 2007

Federal Facilities Environmental Workshop

NextEnergy Center

Detroit, Michigan

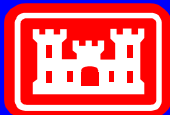


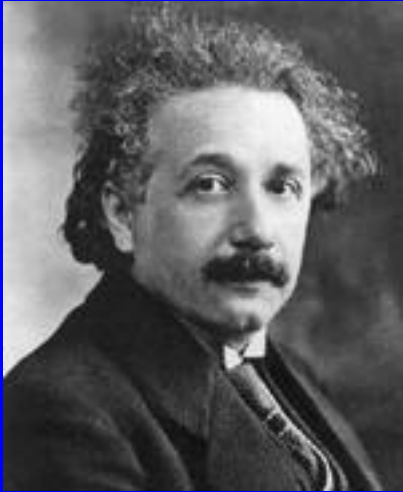
US Army Corps
of Engineers

Engineer Research & Development Center

Workshop Outline

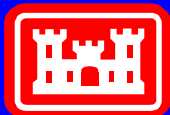
- Welcome / Introductions
- Fuel Cell Review
- DoD PAFC Fuel Cell Projects and Experience
- Site Screening Issues and Discussion
- Thermal Applications - Overview
- Case Studies
- Conclusions





**"Mathematics are well and good but
nature keeps dragging us around
by the nose."**

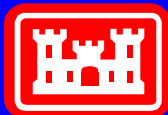
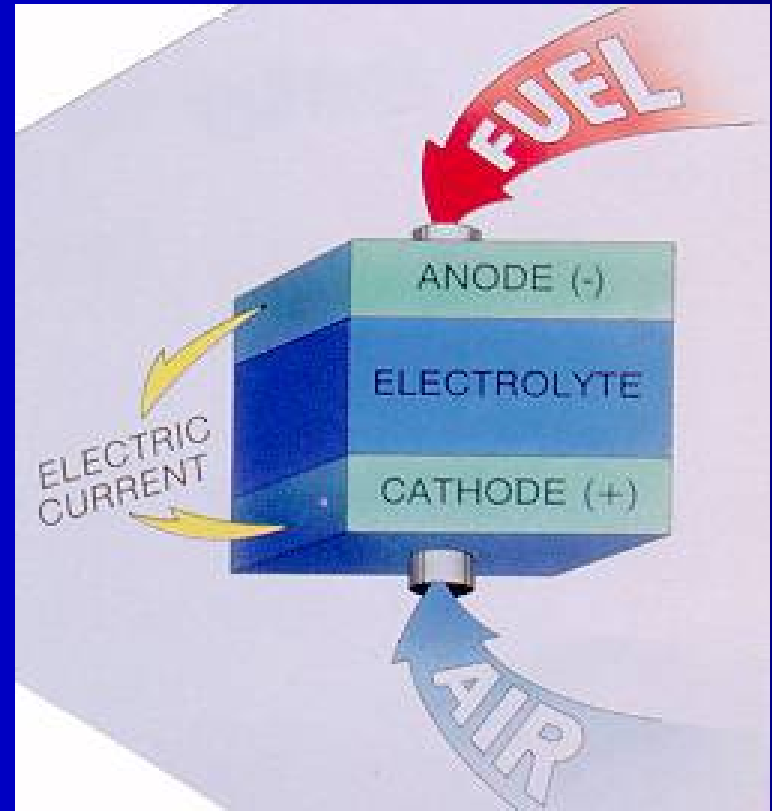
**Quoted in A P French,
Einstein: a Centenary Volume**



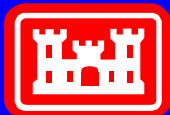
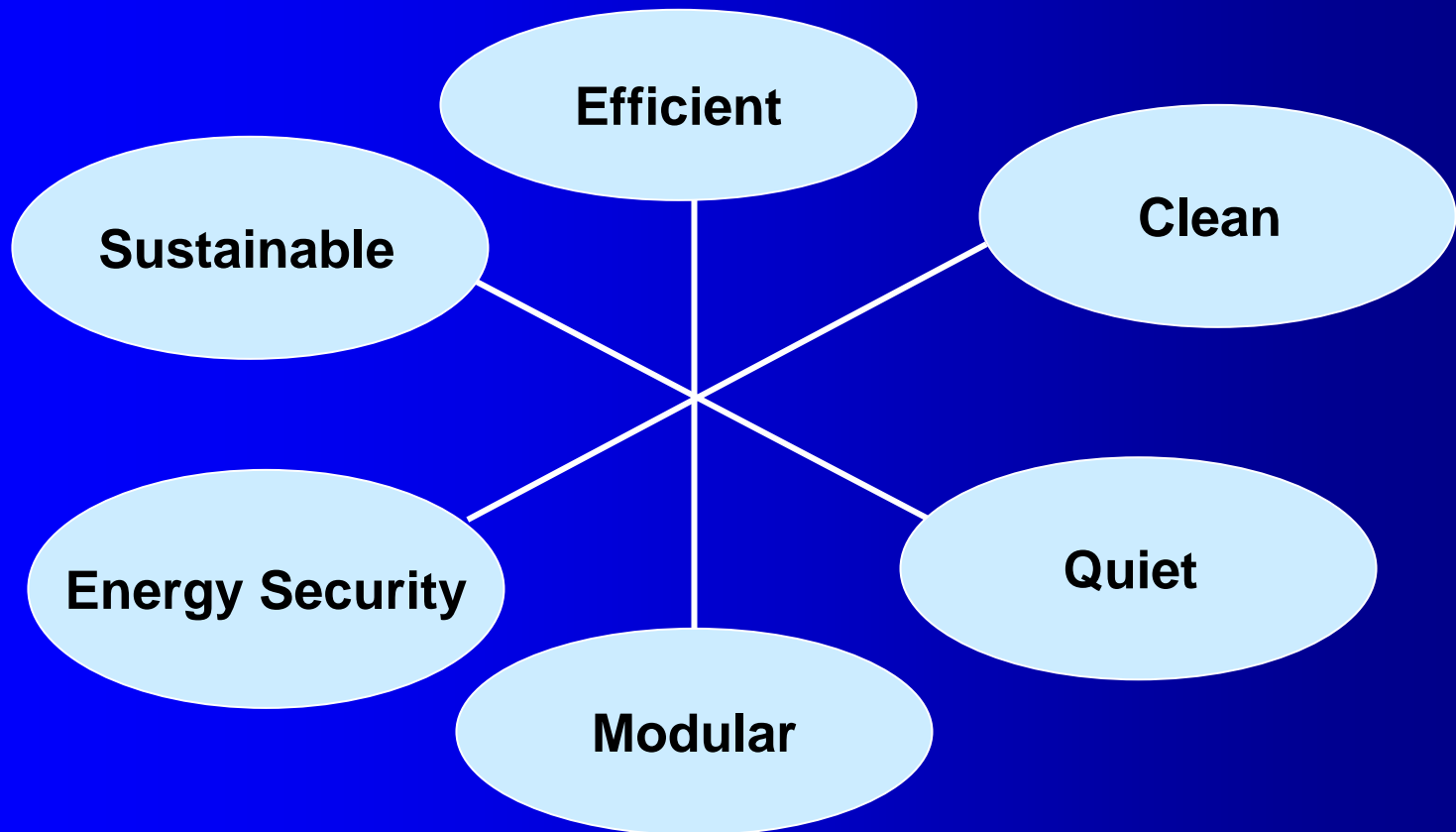
Fuel Cell Concept

A fuel cell consists of two electrodes (anode and cathode) and an electrolyte.

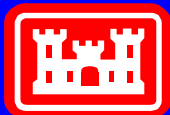
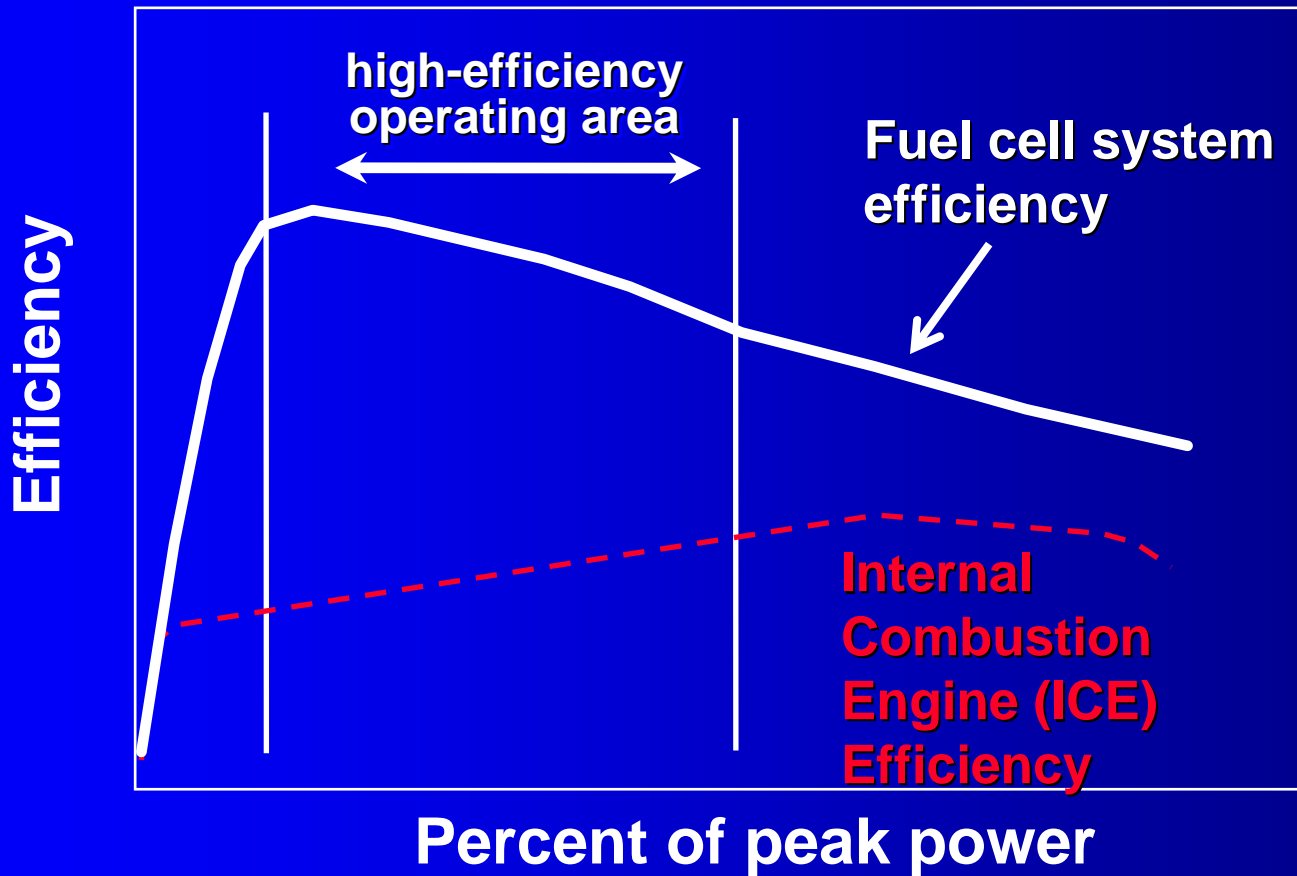
Fuel is introduced into the anode, and an oxidant is introduced into the cathode, generating electricity, water and heat.



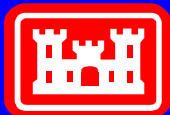
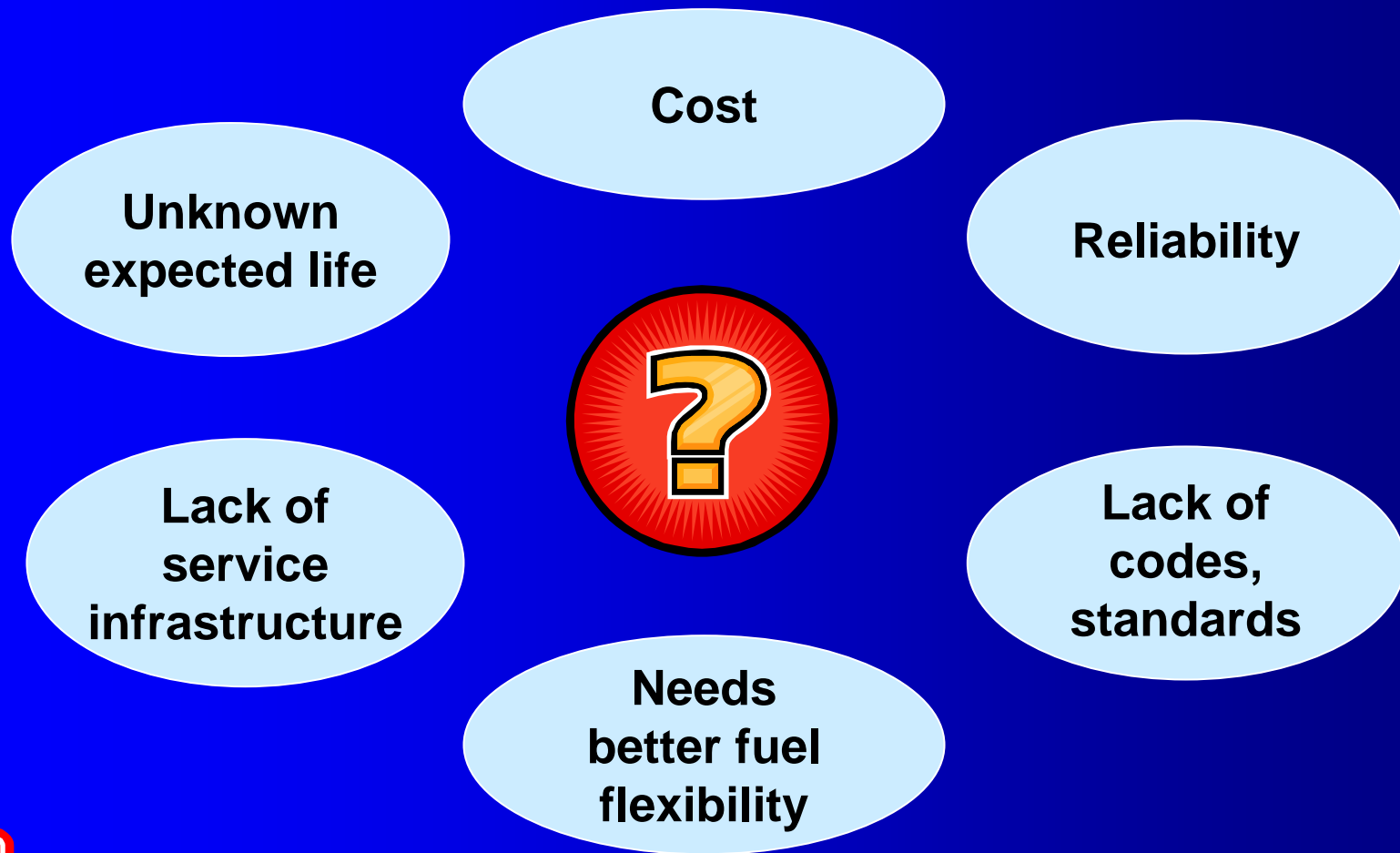
Benefits of Fuel Cells



Fuel Cell Efficiency vs. Load

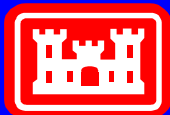


Challenges to Fuel Cell Commercialization



Types of Fuel Cells

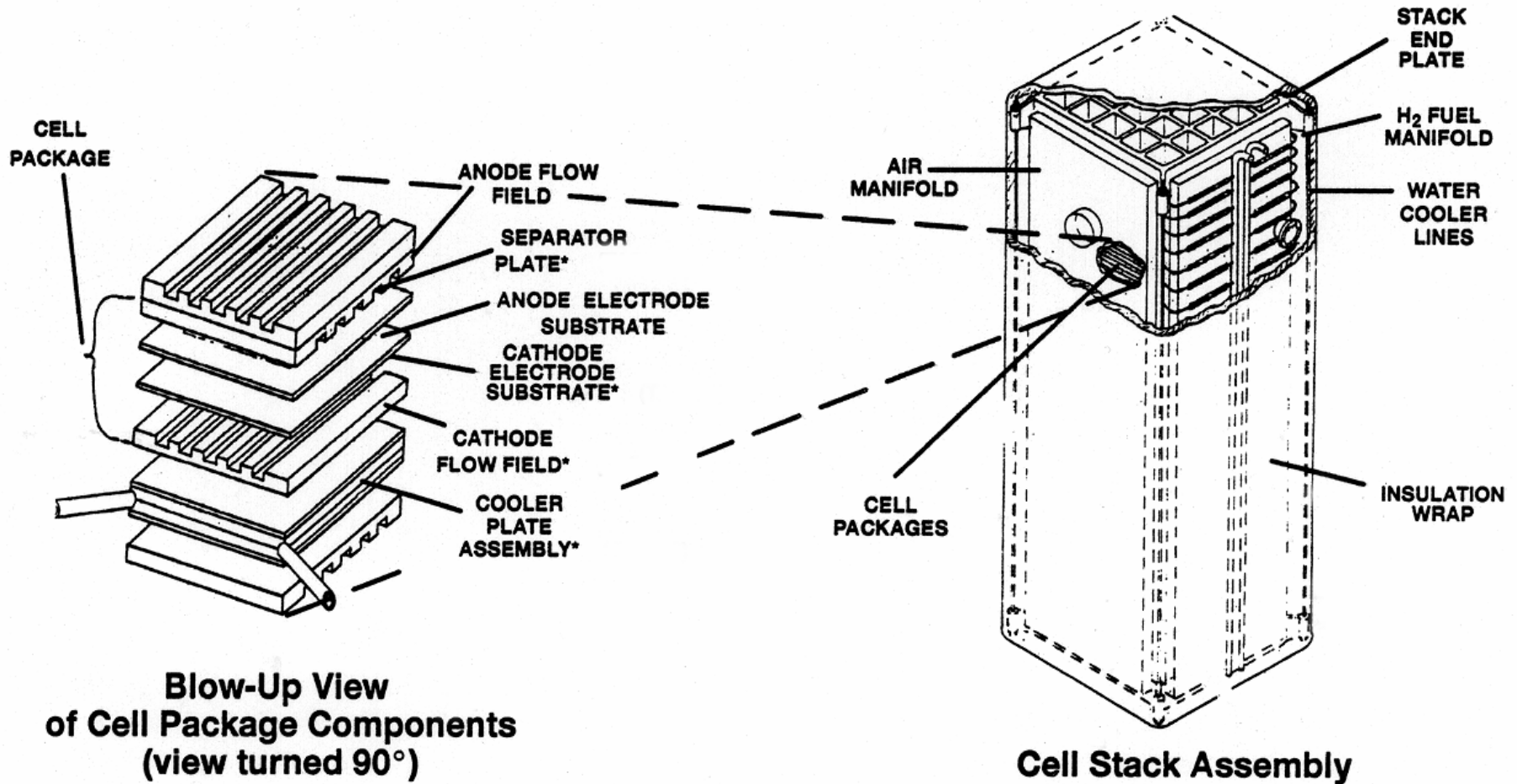
- **Phosphoric Acid Fuel Cell (PAFC)**
- **Molten Carbonate Fuel Cell (MCFC)**
- **Solid Oxide Fuel Cell (SOFC)**
- **Proton Exchange Fuel Cell (PEFC)**
- **Alkaline Fuel Cell (AFC)**



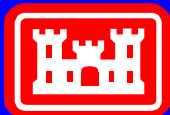
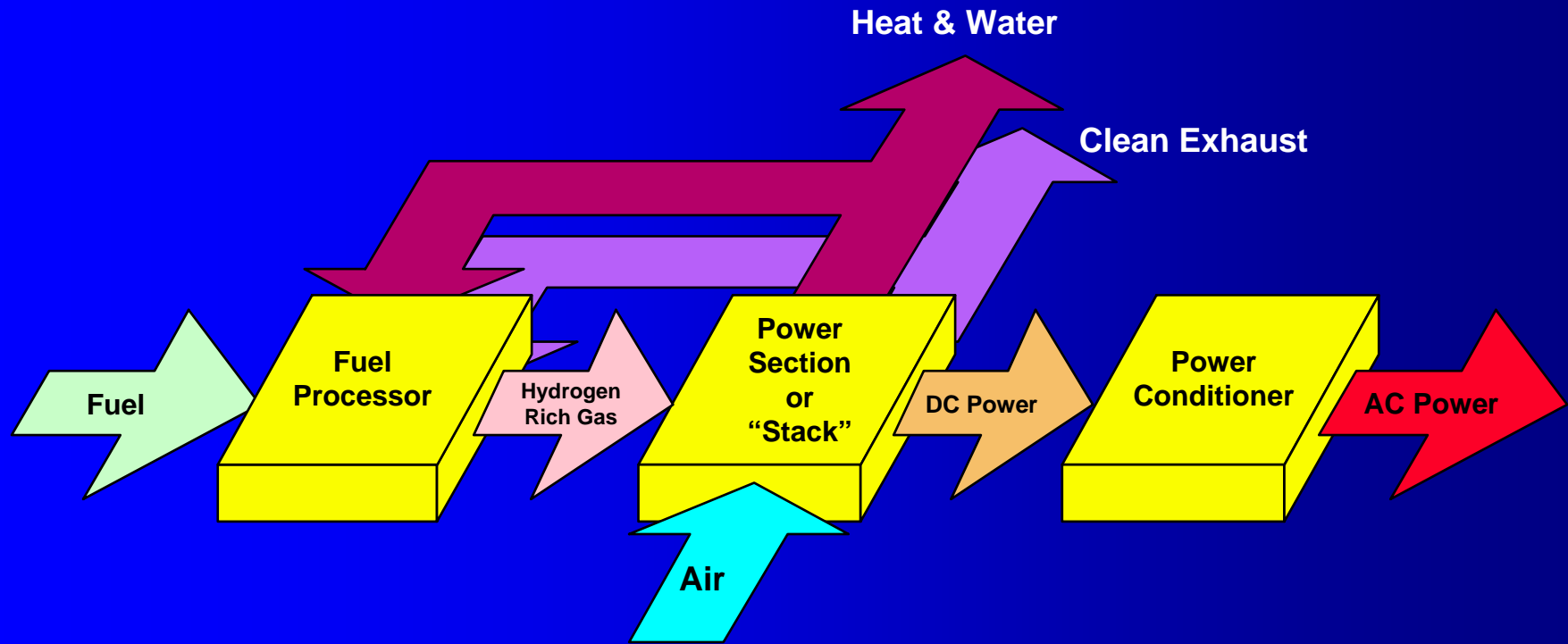
Types of Fuel Cells

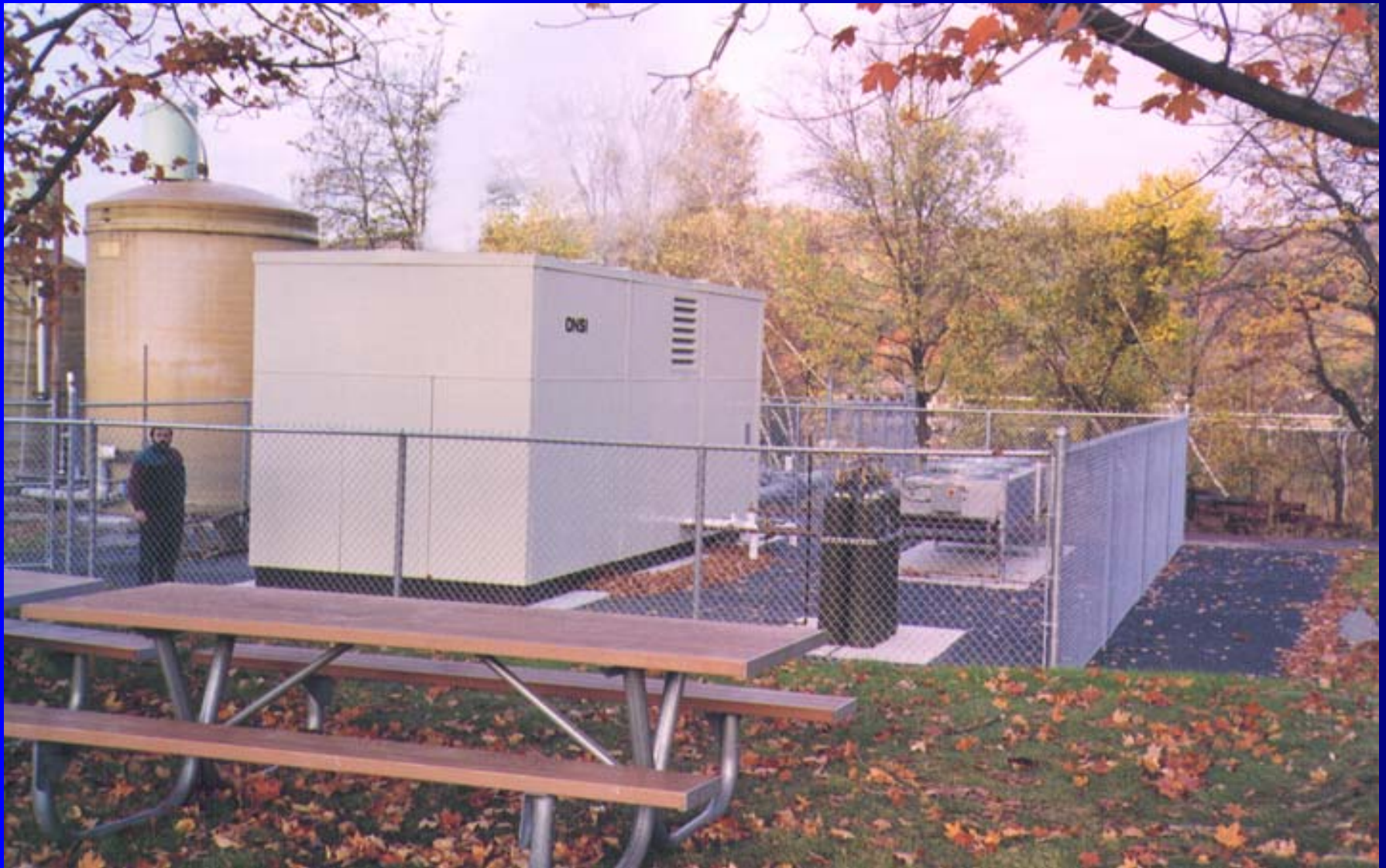
FUEL CELL TYPE	ELECTROLYTE	OPERATING TEMPERATURE	CHARGE CARRIER	APPLICATION & FUEL COMMENTS
AFC	AQUEOUS POTASSIUM HYDROXIDE	~ 80°C	OH⁻	Space, Pure H₂, CO, CO₂ intolerant
MCFC	MOLTEN ALKALI CARBONATES OR SALTS	~650°C	CO₃⁼	Stationary Power Fuel flexibility
PAFC	AQUEOUS PHOSPHORIC ACID	~200°C	H⁺	Stationary Power, Transportation Relatively pure H₂
PEMFC	SOLID POLYMER	~50°C	H⁺	Transportation Pure H₂, CO intolerant
SOFC	SOLID METAL OXIDE (Ceramic)	~1000°C (HIGH) ~ 650°C (LOW)	O⁼	Stationary Power, APU Fuel flexibility

PAFC Fuel Cell Power Plant “Stack” Assembly



Fuel Cell Power Plant Diagram



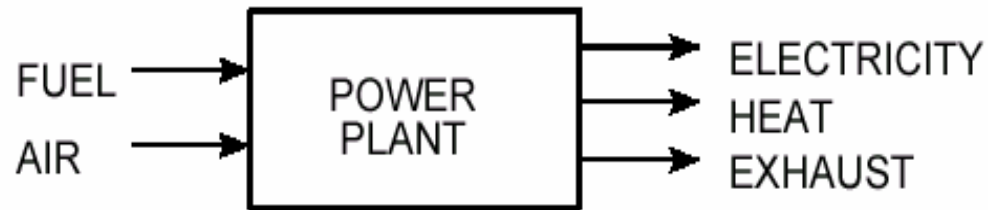


PAFC at Picatinny Arsenal, NJ

UTC Fuel Cells PC25 Power Plant Characteristics

- Phosphoric Acid Electrolyte
- Natural Gas Input - 1900 scf/hr
Anaerobic Digester / Landfill Gas Option
- Electrical Output - 200 kW @ 480V 3ph
- Thermal Output - 900,000 Btu/hr @ 140°F
High Grade - 450,000 Btu/hr @ 140°F and
450,000 Btu/hr @ 250°F
- >80% Overall Efficiency
- Negligible Air Emissions
- Current Cost ~ \$850,000

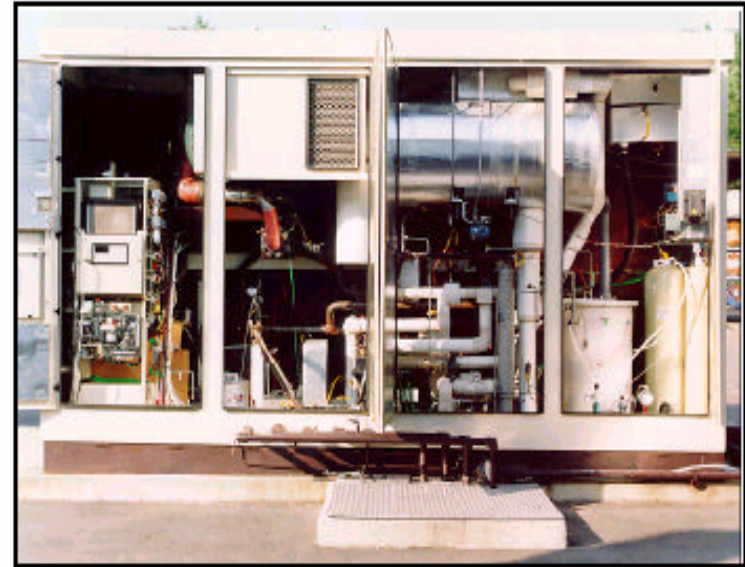




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Major Components

- Fuel Processor
- Cell Stack
- Power Conditioner

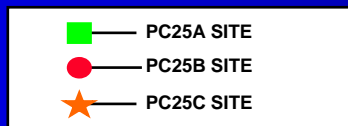
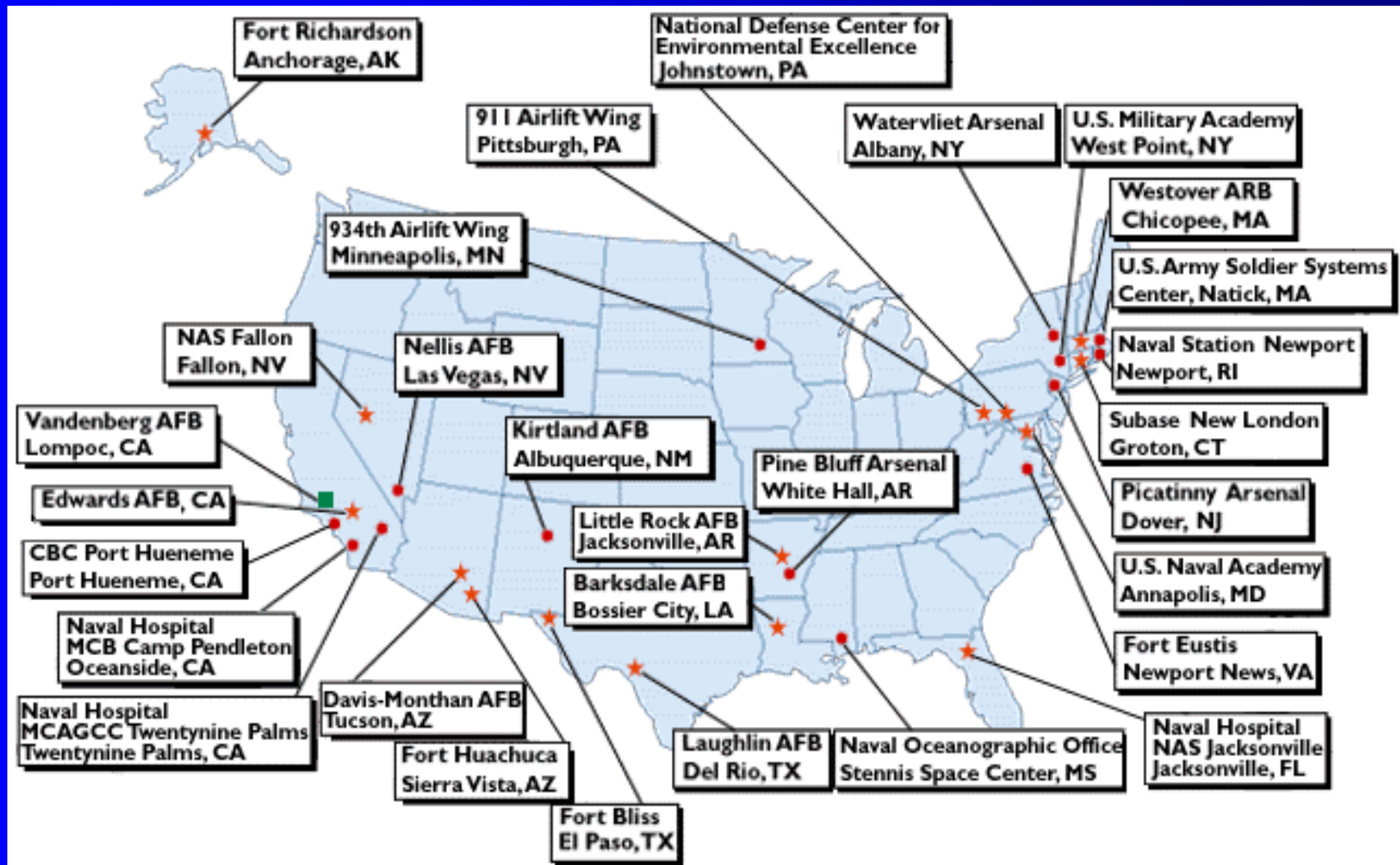


WCN15165

Ancillary Systems

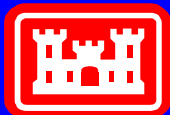
- Fuel and Air Supply
- Heat and Water Management
- Ventilation
- Control, Diagnostics

DoD PAFC Program Sites



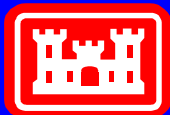
Site Selection Criteria

- Interest / Cooperation of Site Personnel
- Energy Costs / Savings
- Thermal Energy Utilization / Diversity
- Electric Energy Utilization / Diversity
- Geographic / Climatic Diversity
- Physical Considerations
- Environmental Considerations



Turn-key Package

- UTC PC25 Fuel Cell Power Plant
- Engineering Design / Installation
- Training for Site Personnel
- 60 Months Maintenance
- Diagnostic / Remote Monitoring Computer



PAFC Project Process



Site Evaluation / Concept Design

Kickoff Meeting / Design /
Standard Drawings

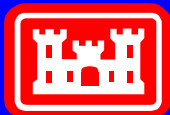


Design Review / Begin construction



Acceptance / Transfer
Ownership to Site

PR Ceremony



US Army Corps
of Engineers

Engineer Research & Development Center

DoD PAFC Facility Applications

- **Central Heat Plants**

11 Sites



- **Hospital Utility Plants**

7 Sites



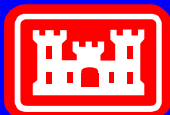
- **Pool / Gymnasiums**

3 Sites



- **Others**

Barracks, Dining Facility, Laundry,
NG Armory, Launch Control Bldg.,
Office, Evaporator process

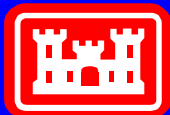


Fleet Performance Summary

(29 Power Plants)

As of October 29, 2003

- Total Run Time 875,345 hrs
- Availability
 - Model B Fleet 57%
 - Model C Fleet 76%
- Energy \$ Saved \$5,959,411
- NOx Abated 281 tons
- SOx Abated 595 tons
- CO Abated 24 tons
- CO₂ Abated 36,043 tons

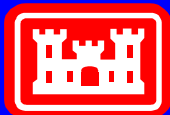


B Fleet Performance Summary

(14 Power Plants)

As of October 29, 2003

- Total Run Time 374,899 hrs
- Availability 57%
- Energy \$ Saved \$2,485,579
- NOx Abated 108 tons
- SOx Abated 267 tons
- CO Abated 10 tons
- CO₂ Abated 11,043 tons

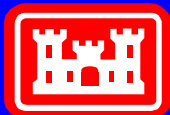


C Fleet Performance Summary

(15 Power Plants)

As of October 29, 2003

- Total Run Time 500,446 hrs
- Availability 76%
- Energy \$ Saved \$3,473,832
- NOx Abated 173 tons
- SOx Abated 328 tons
- CO Abated 14 tons
- CO₂ Abated 25,000 tons



FY93 PAFC Program Sites



934th Airlift Wing, Minneapolis MN



Kirtland AFB, Albuquerque NM



Nellis AFB, Las Vegas NV



Vandenberg AFB, Lompoc CA

FY93 PAFC Program Sites



Naval Hospital, MCAGCC 29 Palms, 29 Palms CA



Naval Hospital, MCB Camp Pendleton, Oceanside CA



Naval Education Training Center, Newport RI



US Naval Academy, Annapolis MD

FY93 PAFC Program Sites



U.S. Army Soldier Systems Command, Natick MA



Ft. Eustis, Newport News VA



Picatinny Arsenal, Dover NJ



U.S. Military Academy, West Point NY

FY94 PAFC Program Sites



911th Airlift Wing, Pittsburgh PA



NAS Fallon, Fallon NV



Ft. Richardson, Anchorage AK



Naval Hospital, NAS Jacksonville, Jacksonville FL

FY94 PAFC Program Sites



Edwards AFB, CA



Barksdale AFB, Bossier City LA



Ft. Huachuca, Sierra Vista AZ



National Defense Center for Environmental Excellence
(NDCEE), Johnstown PA

FY94 PAFC Program Sites



CBC Port Hueneme, Port Hueneme CA



Laughlin AFB, Del Rio TX



**Naval Oceanographic Office
John C. Stennis Space Center, MS**



Westover ARB, Chicopee MA

FY94 PAFC Program Sites



Ft. Bliss, El Paso TX



Subase New London, Groton CT



Little Rock AFB, Jacksonville AR



Pine Bluff Arsenal, White Hall AR

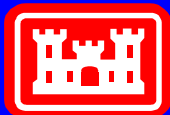
FY94 PAFC Program Sites



Watervliet Arsenal, Albany NY



Davis-Monthan AFB, Tucson AZ



PAFC Scheduled Maintenance (4 - 6 months)

- **Replace Water Treatment System (WTS) Beds & Filters**
- **Replace Air Filters**



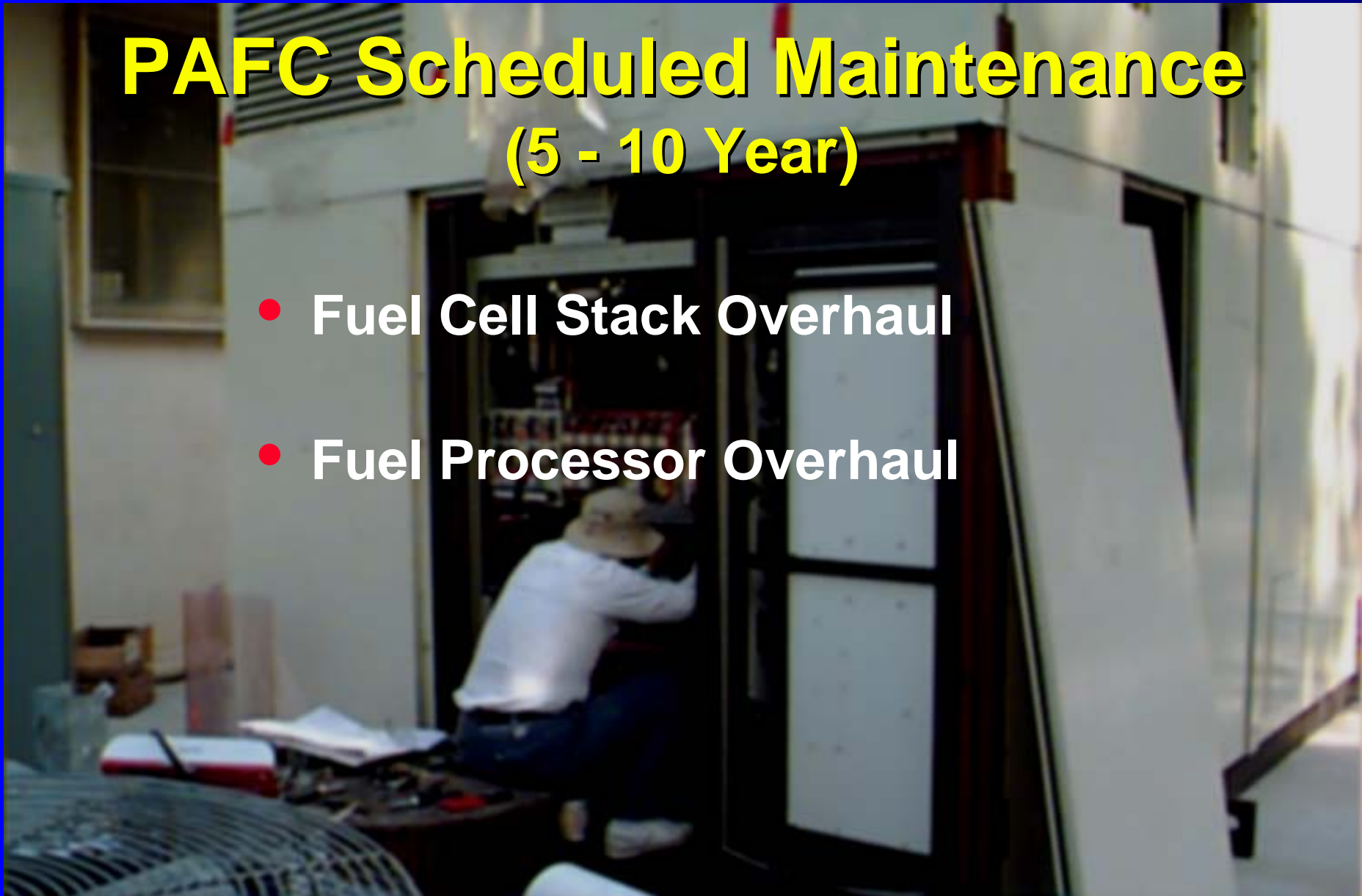
PAFC Scheduled Maintenance (Annual Shutdown)

- **Replace WTS Beds & Filters**
- **Replace Air Filters**
- **Inspect Pressure Vessels**
- **Check Relief Valves**
- **Check & Service Motor Bearings**
- **Clean Water Tank**



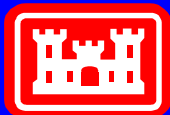
PAFC Scheduled Maintenance (5 - 10 Year)

- **Fuel Cell Stack Overhaul**
- **Fuel Processor Overhaul**



Site Screening Issues Group Discussion

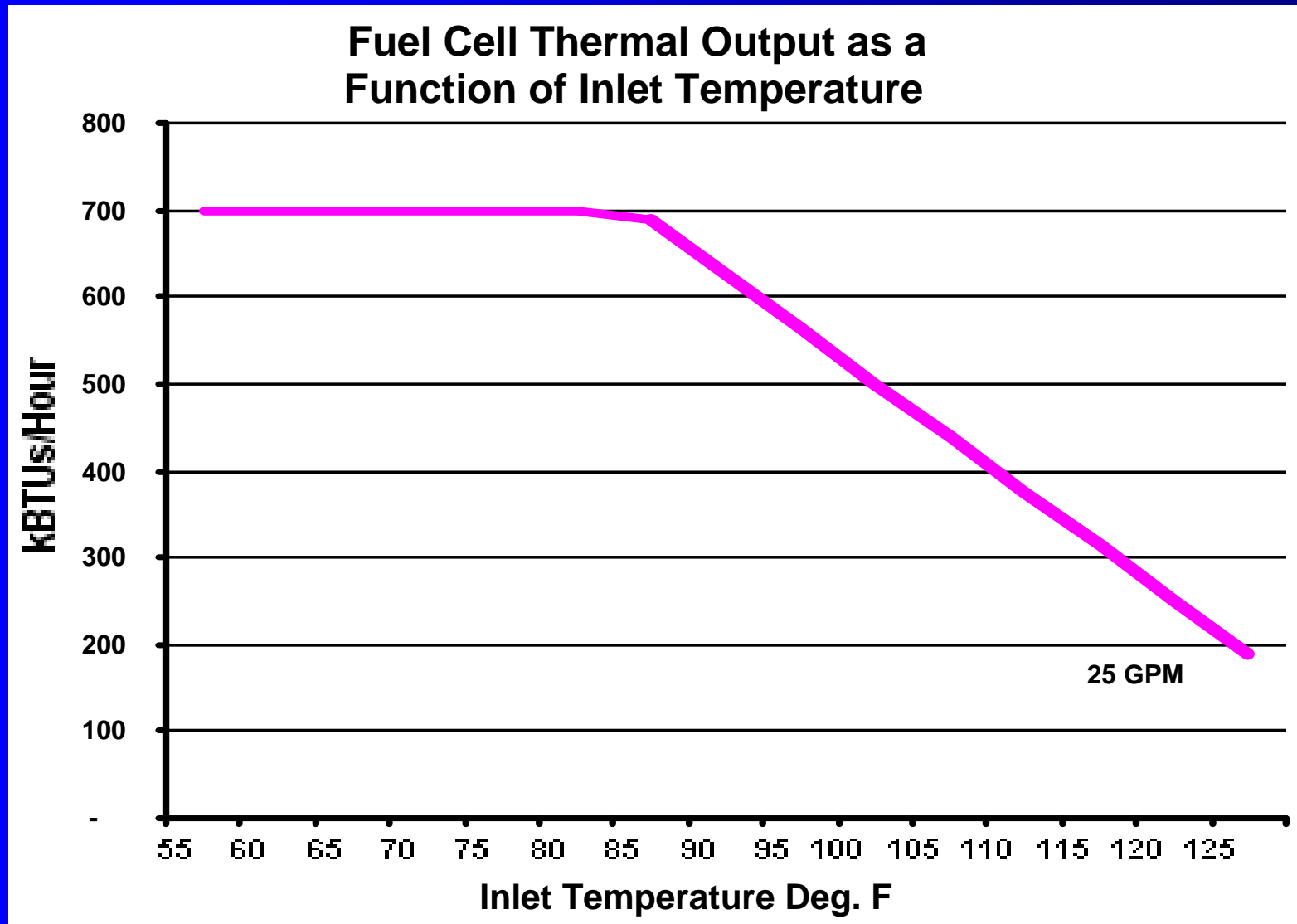
What are the Pertinent Issues for Installing
a Fuel Cell at Your Site??



Potential Thermal Applications at Various Building Types

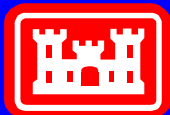
	Boiler Make-up Water	Boiler Return Loop	Domestic Hot Water	Space Heating	Absorption Cooling	Pool Heating	???
Central Heating Plant	X	X					
Hospital	X	X	X	X	X	X	
Dormitory/ Barracks			X	X	X		
Gymnasium/ Pool			X	X	X	X	
Office Building			X	X	X		
Laundry			X	X	X		
Kitchen			X	X	X		
???							

Manufacturer's Specifications for Heat Recovery



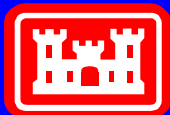
Boiler Thermal Applications

Two thermal loads for a boiler plant are make-up water and return water. If a boiler distribution system is well maintained, make-up water requirements will likely be low. For high make-up water requirements, pre-heating boiler make-up water represents a good application for a fuel cell power plant. Load characteristics will depend on the loads on its thermal loop, time of year, and site specific factors. Most boilers have a log which documents fuel consumption and make-up water requirements.



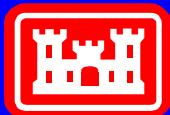
Domestic Hot Water (DHW) Thermal Applications

DHW is used for a variety of purposes including showers, laundry, kitchen loads, etc. In dormitories or hotels, thermal loads typically peak in the morning and evening periods with little or no demand in the middle of the day and night. To provide a buffer to accommodate the load spikes and to maximize the heat recovered from the fuel cell, a thermal storage tank should be considered. If the hot water loop has recirculation, this should be evaluated as a potential heat recovery load. Values for typical dormitory hot water loads are provided in the ASHRAE Handbook of Applications in the chapter on Service Water Heating.



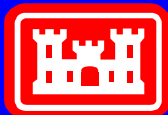
Space Heating Thermal Applications

Space Heating Loops. Hot water space heating loops generally operate at temperatures that require the high-grade heat exchanger (UTC) option. Thermal utilization is limited to the months where space heating is required (4 to 7 months). Heating degree days for a location can be used to determine the potential load requirements. The heating load can be extended year around by using the heating loop to control humidity in a cool-reheat application.



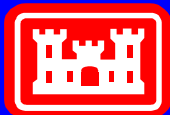
Swimming Pool Thermal Applications

Swimming pools have both make-up water requirements (due to evaporation and spillage) and pool reheat requirements. The thermal load demand will vary depending on whether the pool is indoors or outdoors, the ambient temperature and humidity, the wind velocity, whether the pool is covered or not, the pool size and other site specific variables. Indoor pools generally have lower heat losses than outdoor pools, but also tend to be open year round.



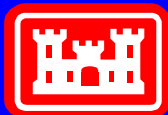
Absorption Cooling Thermal Loads

Using the high-grade heat exchanger option (ONSI), the fuel cell power plant can provide heat to an absorption chiller to provide cooling to a building. Absorption chillers are one way to create a thermal load for a fuel cell when no other loads are available. If electric rates are high in the cooling season, then displaced cooling using an absorption chiller can be cost effective. Sites with longer cooling seasons or requiring continuous cooling (hospitals, etc.) are the best candidate sites for this technology.



Thermal Interface Issues

- Potable Water Requirements
- Retrofit System Design
- High/Low- Grade Heat Exchangers
- Temperature Compatibility
- Pipe Material Compatibility
- Low / Intermittent Thermal
- Water Separation
- Changing Site Characteristics



PAFC Case Study 1: Central Heating Plant

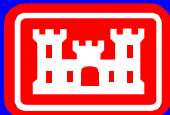


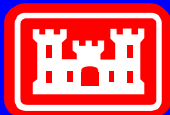
Picatinny Arsenal
Dover, NJ

PC25B - October 1995

Electrical: Grid-connected at existing panel.

Thermal: Pre-heat boiler make-up water.
No condensate return.





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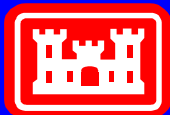
PAFC Case Study 1: Site Evaluation Data

Length of Piping/Wiring Runs:

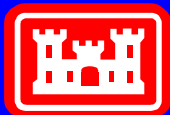
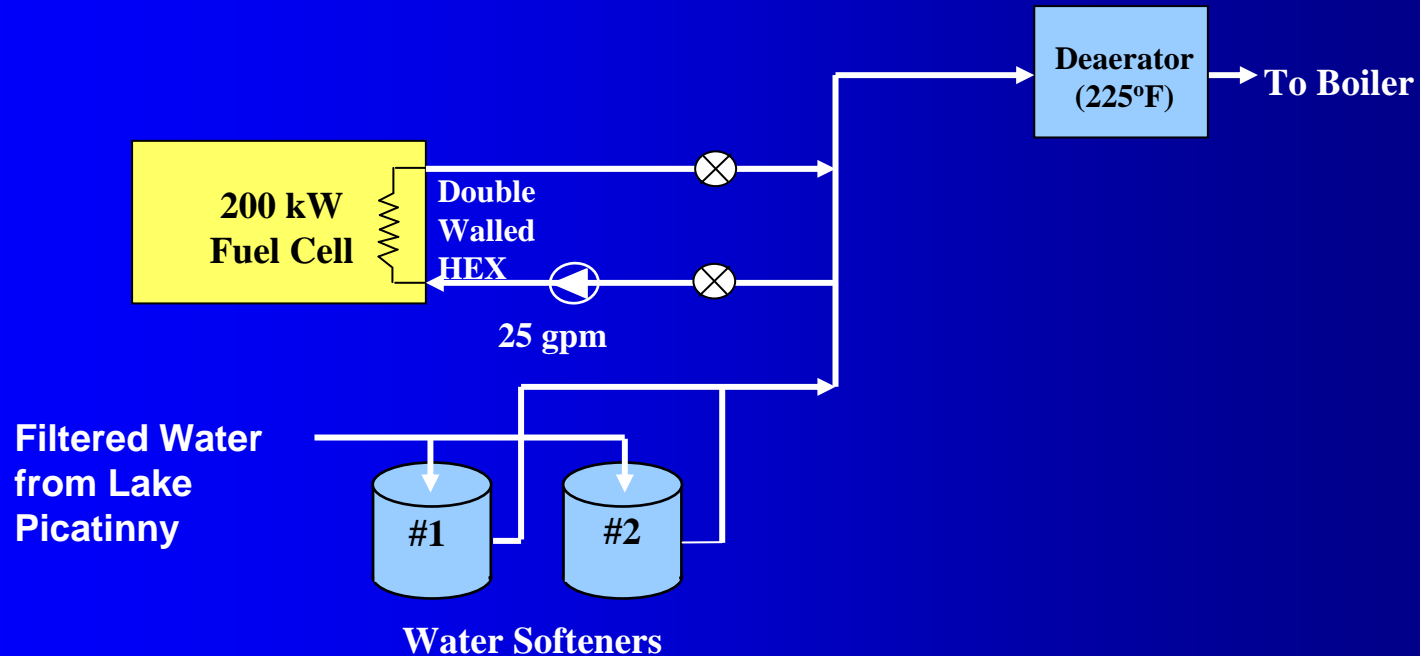
Electrical (to transformer)	~250 feet
Thermal (to mech. Room)	~200 feet
Natural Gas	~25 feet
Cooling Module	~20 feet

Estimated Energy Bill Savings:

Electrical Savings	\$121,000
Thermal Savings	\$ 25,000
Natural Gas Cost	(\$ 52,000)
NET SAVINGS:	\$ 94,000

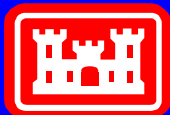


PAFC Case Study 1: Thermal Interface



PAFC Case Study 1: Results Summary

- Make-up water from nearby Lake Picatinny.
- Heat Recovery exceeds 1 MMBtu/hour on occasion.
- Highest thermal recovery in Program.



PAFC Case Study 2: Hospital Space Heating Loop

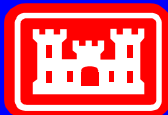


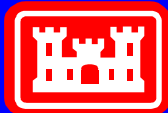
Edwards Air Force Base
Edwards AFB, CA

PC25C - July 1997

Electrical: Grid-connected at site transformer.

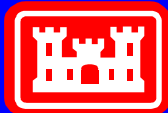
Thermal: Pre-heat space heating return loop
prior to steam heat exchanger.





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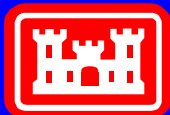
PAFC Case Study 2: Site Evaluation Data

Length of Piping/Wiring Runs:

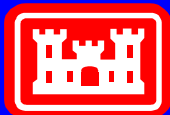
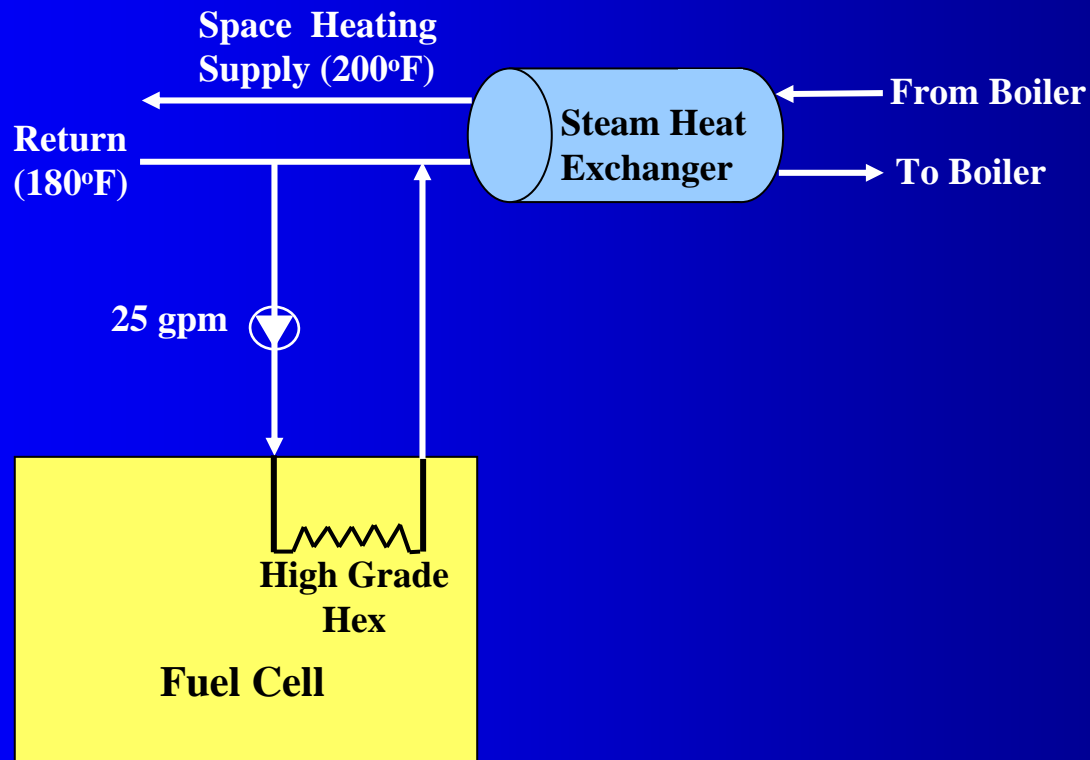
Electrical (to transformer)	~60 feet
Thermal (to space heat loop)	~20 feet
Natural Gas	~40 feet
Cooling Module	~20 feet

Estimated Energy Bill Savings:

Electrical Savings	\$122,000
Thermal Savings	\$ 3,000
Natural Gas Cost	(\$ 29,000)
NET SAVINGS:	\$96,000

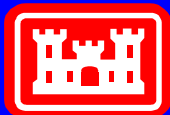


PAFC Case Study 2: Thermal Interface



PAFC Case Study 2: Results Summary

- Year round space heating requirement (unusual).
- High-grade heat exchanger required.
- Average load estimated to be 1/2 the output capacity of high-grade heat exchanger.



PAFC Case Study 3: Swimming Pool



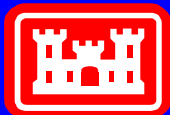
Fort Eustis

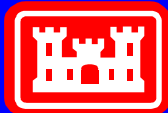
Newport News, VA

PC25B - September 1995

Electrical: Grid-connected at site transformer.
Grid-independent connection.

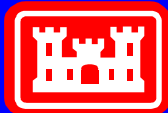
Thermal: Swimming pool make-up water and
pool recirculation loop.





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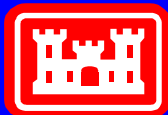
PAFC Case Study 3: Site Evaluation Data

Length of Piping/Wiring Runs:

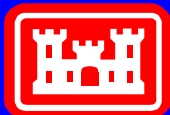
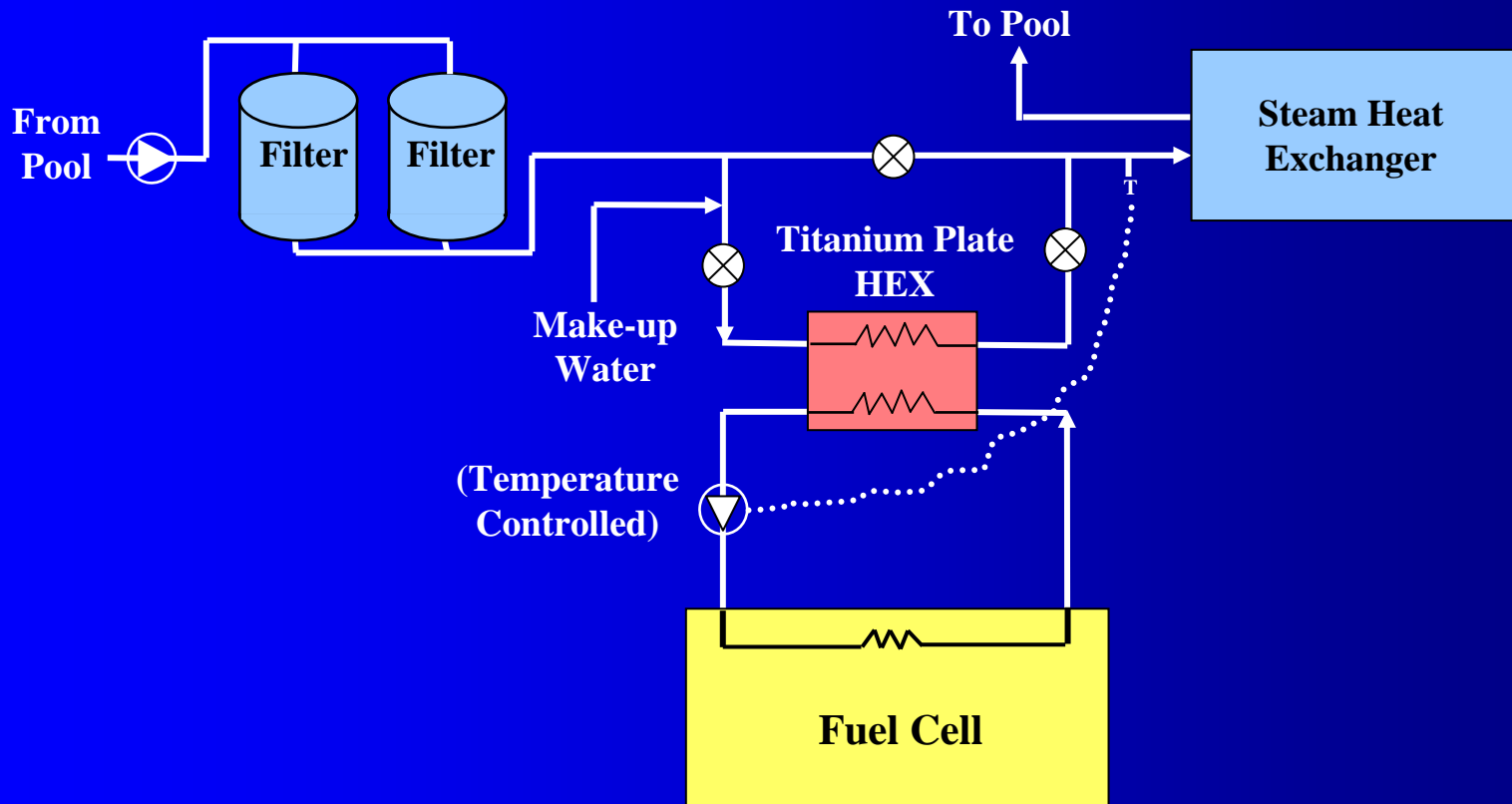
Electrical (to transformer)	~80 feet
Thermal (to mech. Room)	~20 feet
Natural Gas	~250 feet
Cooling Module	~20 feet

Estimated Energy Bill Savings:

Electrical Savings	\$ 62,000
Thermal Savings	\$ 20,000
Natural Gas Cost	(\$ 41,000)
NET SAVINGS:	\$41,000

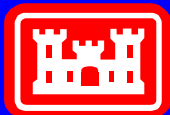


PAFC Case Study 3: Thermal Interface



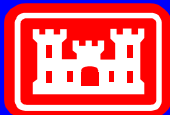
PAFC Case Study 3: Results Summary

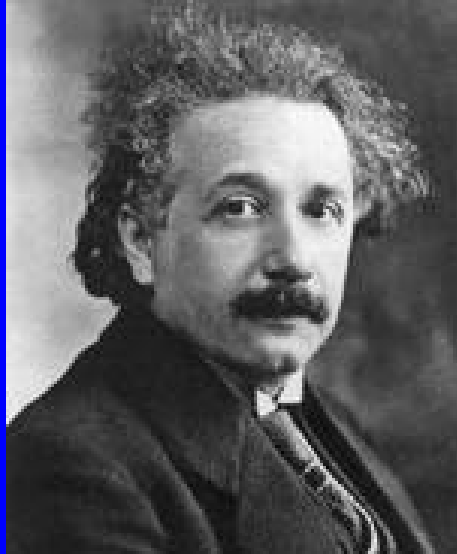
- Intermediate heat exchanger required to separate water streams.
- Pool water leak repairs reduced the 60% thermal utilization estimate to 18%.
- Gas rate structure limited fuel cell operation to 7-8 months per year.



Case Studies/Appendices

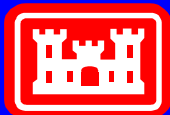
- **Boiler System**
- **Domestic Hot Water System**
- **Space Heating System**
- **Swimming Pool**
- **Absorption Cooling System**





"Everything should be made as simple as possible, but not simpler."

**Albert Einstein
Reader's Digest. Oct. 1977**



**US Army Corps
of Engineers**

Engineer Research & Development Center

Conclusions

- Successful demonstration of fuel cell cogeneration in a wide variety of building and climate applications.
- Thermal interface was most significant site issue in DoD Program.
- Many conceptual and technical lessons learned that can be applied to future projects.
- *Please visit - <http://www.dodfuelcell.com> for more information.*

